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NEUROLOGIC GAIT ANALYSIS, TREATMENT & MEASUREMENT

Case-Based Interventions for the PTA
Part III: Lesions of the Cerebellum

Liability/Disclosure Statement

Objectives

1. Correctly identify at least two areas of the cerebellum given the functional anatomy.
2. Accurately identify one impairment typically seen during gait based on a given cerebellum lesion post-stroke.
3. Independently modify at least three therapeutic interventions related to impairments of muscle tone discoordination, and or sensory loss.
4. Correctly match at least two gait impairments to cerebellum lesion location seen post-stroke given a case study.

Outline

1. Cerebellum Brain Functional Anatomy
2. Normal Gait Analysis
3. Gait Impairments Related to Cerebellum Brain Lesions
4. Treatment Interventions to Improve Gait Impairments as a Result of Cerebellum Brain Lesions
5. Case Study
6. Knowledge Summary

How many of you have a continuing education course in neurorehabilitation targeting the PTA? Yes or No

Poll Question 1

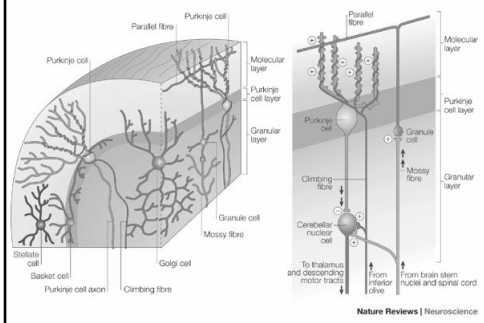
In which setting have or do you currently work?

a. Acute hospital
b. Inpatient rehab
c. Outpatient rehab
d. Subacute rehab
e. Home health

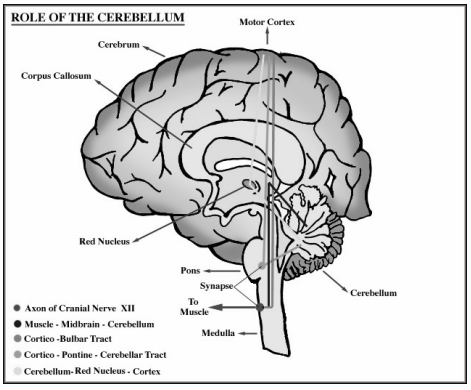
Poll Question 2

Cerebellum Brain Functional Anatomy

Cellular Anatomy[1-4]



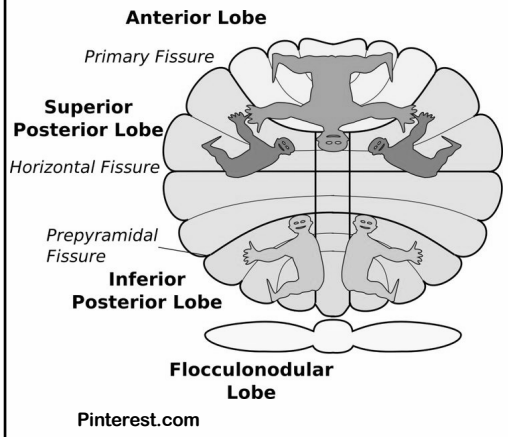
Humanphysiology.academy.com



Csuchico.edu

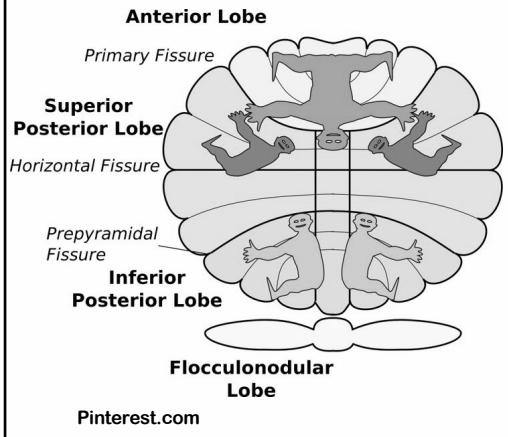
8/16/2017

Anatomy by Lobes[1-4]



- Anterior: superior separated from posterior lobe by primary fissure
  - cells degenerate with alcoholism
  - Regulation of mm tone & coordination of skilled mm mov't

Anatomy by Lobes[1-4]



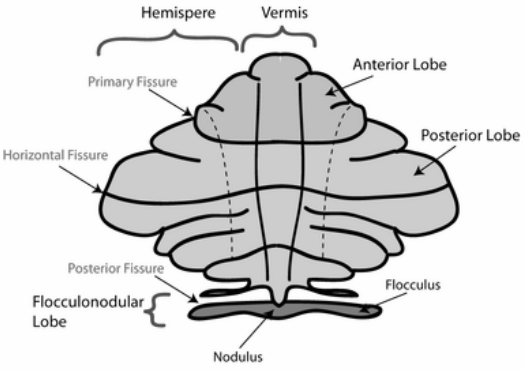
Posterior Lobe: superior

Posterior Lobe: inferior
- Planning of voluntary activity

Floccunodular Lobe

Maintenance of balance and control of eye mov'ts

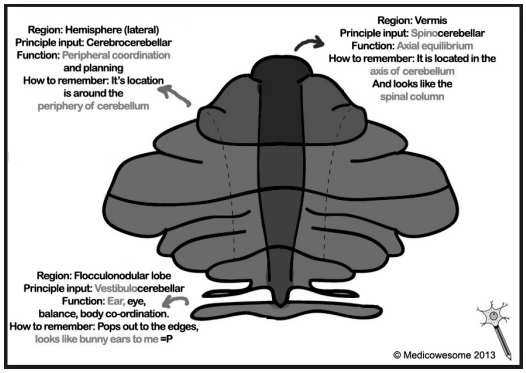
Functional Anatomy – Vertical Body Representation[1-4]



En.Wikipedia.org

- Vermis=trunk
- Hemisphere
  1. Paravermis=shoulder girdle & pelvis; proximal limbs
  2. Lateral hemisphere=distal limbs

Functional Division by Anatomic Connections[1-4]



Medicowesome.com

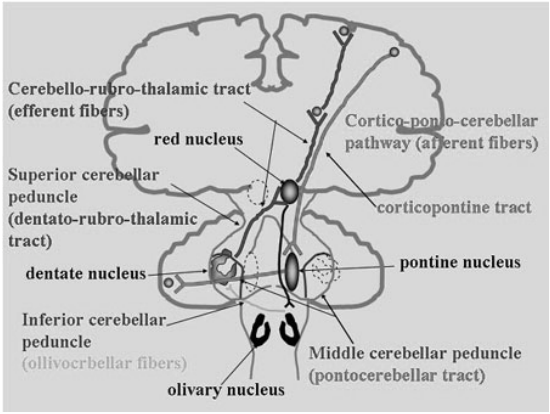
- Spinocerebellum: vermis & paravermis - talks to spine
- Cerebrocerebellum: talks to cerebral cortex (lateral hemisphere)
- Vestibulocerebellum; flocculonodular lobe - talks to vestibular system

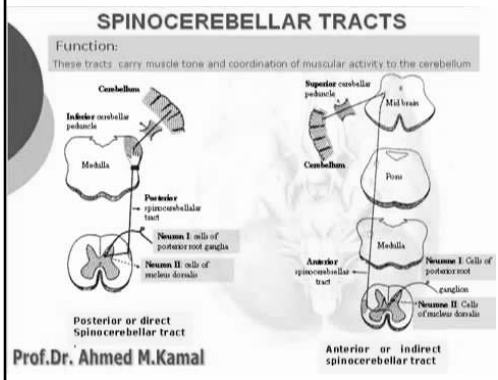
Cerebellum[1-4]

- Part of extrapyramidal system
- Critical for learning mov't & readjusting previously learned mov't
- Coordinates rate, rhythm & timing of mov't & gauges postural control
- How? Comparison of actual w/ intended mov't, then adjusts mov't

Intended Movement[2]

Intended mov't: corticopontine tract→ pontine nuclei → cerebellum





https://www.youtube.com/watch?v=CjlBqmv4KNw

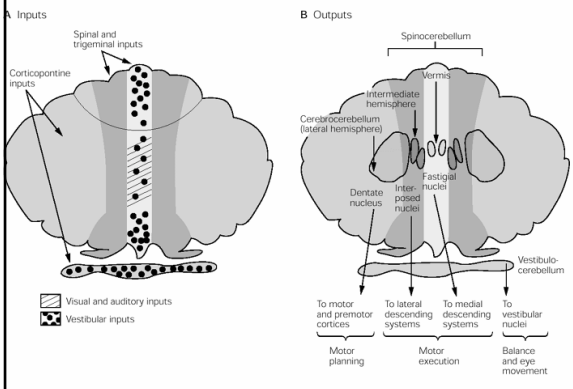
Posture[2]:

- receives info from Anterior & Rostral Spinocerebellar tracts about activity of spinal interneurons

Actual mov't info provided by[2]:

- Muscle spindles, GTOs, Cutaneous Mechanoreceptors
- Posterior spinocerebellar tracts & Cuneocerebellar tracts

Nuclei[1-4]

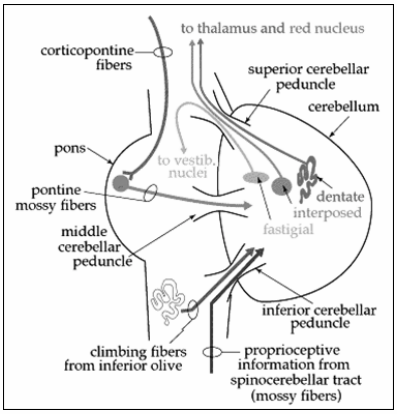


Fastigial: interprets body motion via fxn w/ antigravity mm grps involved in stand & walking; vestibular system – saccadic eye mov'ts

Interposed=globose & emboliform: coordinates agonist/antagonist mm coordination

Dentate: planning, initiation and control of voluntary movements

Peduncles: Tracts Enter & Exit Cerebellum



Efferent Info:

1. Vestibular nuclei (base of pons)
2. Reticular (brainstem)
3. Red nucleus (subcortical region)
4. Motor nuclei (thalamus)

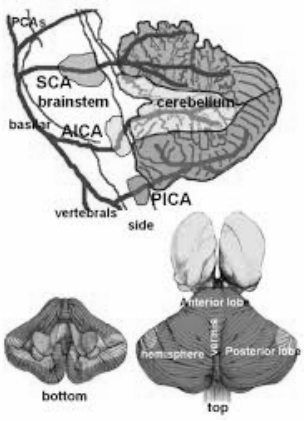
Afferent info:

1. Mossy fibers
2. Climbing fibers

Functional Region Movement Review

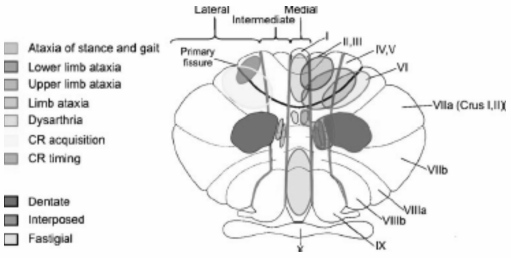
Region	Function
1. Vermis	1. Equilibrium – trunk posture
2. Paravermis	2. Gross movements of limbs
3. Lateral hemisphere	3. Fine, distal, voluntary movements
4. Flocculonodular Lobe	4. Vestibular system, equilibrium-trunk posture

Arterial Supply[1-4]



- Superior Cerebellar Artery: vermis paravermis, anterior lobe – can get lateral hemisphere
- Anterior Inferior Cerebellar Artery: underside of cerebellum next to brain stem & flocculonodular lobe; lateral hemisphere; vermis, paravermis
- Posterior Inferior Cerebellar Artery: posterior lobe - can get lateral hemisphere; vermis, paravermis

Clinical Notes



Central vertigo signs[6]:
1. severe ataxia
2. Inability to walk w/o support

- SCA: pertinent structures controlling limb & gait are in superior portion of cerebellum[5]
-
- PICA:10% of pt w/ cerebellar infarct will get vertigo with NO other neuro findings of motor, sensory, reflex, cranial nerve or limb coordination deficits[6]

A person presents with truncal ataxia.
The lesion is most likely in the _____.
a. paravermis
b. lateral hemisphere
c. vermis
d. medial hemisphere

Poll Question 3

Normal Gait Analysis

GAIT	WALKING
□ Locomotion of human body □ Bipedal, biphasic forward propulsion of the body's center of gravity (COG) of the human body; alternating movements of different body segments using the least amount of energy □ Walk, jog, run, sprint= types of GAIT Wikipedia.org	1 foot in contact with the ground at all times 1. Lift 1 leg off of the ground 2. Using leg in contact w/ ground, push body forward 3. Swing lifted leg forward until it is in front of body 4. Fall forward to allow lifted leg to contact the ground 5. Repeat steps 1–4 for opp LE 6. Repeat steps 1–5 to continue walking

GAIT: Definitions[6]

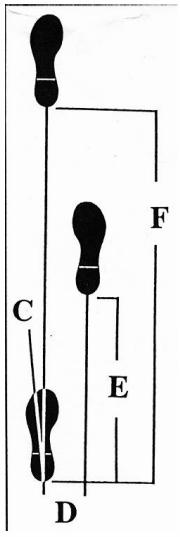
E. Step Length: heel of one foot to heel of opposite foot

F. Stride Length: heel to heel same foot

C. Angle of Toe Out

D. Width of Base of Support

- Velocity: distance/time; (feet/min or m/sec)
- Cadence: # of steps/time
- 100-120 steps/min: normal speed of gait



3 Main Functions of Gait[7]

1. Weight Acceptance: IC & LR
   a. outstretched limb/shock absorption
   b. forward momentum/progression
   c. limb stability

2. Single Limb Support: MSt & TSt
   a. body weight advances over (forward progression) & ahead of single stable limb

3 Main Functions of Gait[7]

3. Single Limb Advancement: PSw, Isw, MSw, & TSw
   a. from behind to ahead of body
   b. foot clears the ground

Review of Gait Functions[7]

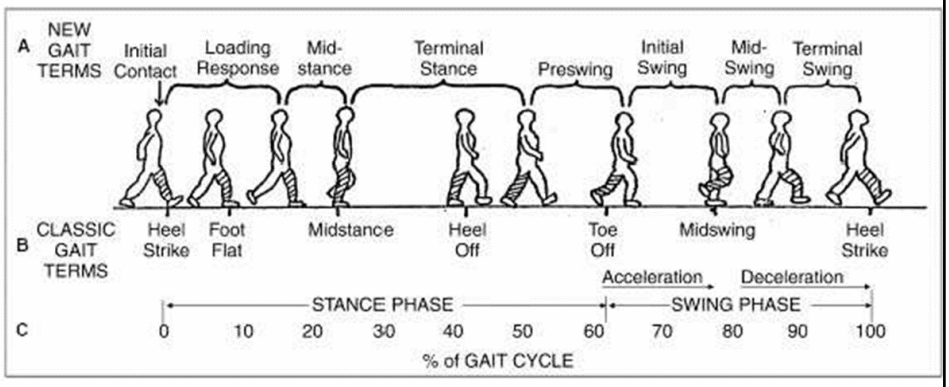


Illustration courtesy of Carson Schneck, MD

[7]1 Gait Cycle: 1^0 contact to 1^0 contact of same foot

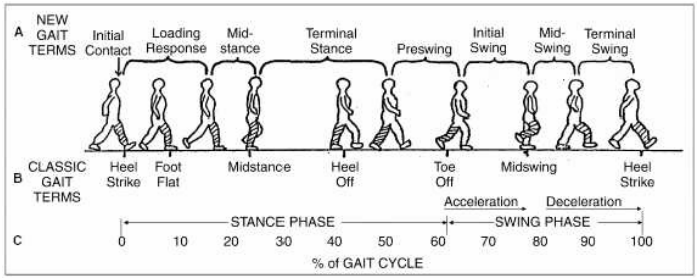


Illustration courtesy of Carson Schneck, MD

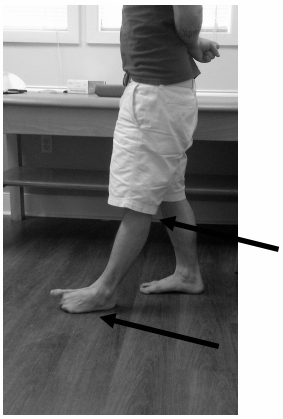
- 62% STANCE: initial contact to preswing
- 38% SWING: initial swing to terminal swing

Initial Contact[7]

Critical Features

1. **Heel strike**
   - **Initiate heel rocker**
   - **Decelerate impact**

Loading Response[7]



Critical Features

1. **Controlled heel rocker**
2. **Stable hip**
3. **Controlled knee flexion**
4. **Controlled ankle plantarflexion**

Midstance[7]

Critical Features

1. Controlled ankle [midfoot] rocker & tibial advancement
2. Knee extension 0˚-5˚
3. Frontal plane pelvic stability

Terminal Stance[7]

Critical Features

1. Controlled forefoot rocker (30˚ metatarsal-phalangeal joint extension)
2. Dorsiflexion 10˚ with heel rise
3. Trailing limb
4. Forward momentum - COM

Preswing[7]

Critical Features

1. Passive knee flexion to 40˚
2. Ankle plantarflexion 15˚
3. 60˚ metatarsal-phalangeal extension – forefoot rocker

Initial Swing[7]

Critical Features

1. Hip flexion 10˚-15˚
2. Knee flexion 45˚-60˚

Midswing[7]

Critical Features

1. Hip flexion 25˚ (maximum flexion)
2. Ankle dorsiflexion 0˚; tibial vertical; neutral inversion/eversion

Terminal Swing[7]

Critical Features

1. Full knee extension 0˚-5˚
2. Forward pelvic rotation needed for increase step length
3. Hip deceleration
4. Ankle 0˚

What is true about initial swing?

a. Foot clearance requires 45-60˚ of knee flexion
b. The tibia moves forward on the femur
c. The hamstring muscle works concentrically
d. Initial swing is a part of stance phase

Poll Question 4

Gait Impairments

Related to Cerebellum Brain Lesions

Truncal Ataxia

- https://www.youtube.com/watch?v=H3TZvxoOc10

Research by Bastian et al 2003[7] & Morton & Bastian, 2003[8] & 2009[9]

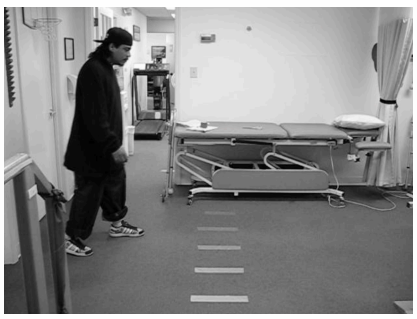
Balance deficits (trunk) & NO leg coordination deficits	Leg coordination deficits & NO balance deficits (trunk)
□ Reduced stride lengths □ Increased stride widths □ Reduced joint excursions □ Abnormal swing foot trajectories □ Increased variability in foot placement □ Decomposition btwn ankle & knee joint □ Reduced walking speed	□ Did Not have significant walking impairments □ Therefore: trunk *imbalance* appears to contribute more strongly to cerebellar gait ataxia than leg coordination deficits

Limb Ataxia vs Discoordination Problem

- https://www.youtube.com/watch?v=fwG6CUD6Puw

- Ataxia general term which means incoordination of mov't & often applied to gait[10]
- Discoordination: proprioceptive deficits NOT weakness

Example of Coordination Deficits RLE



Terms Related to Gait Impairments[1-4,11]

- Asynergy: loss of coordination
- Tremors: begin with intentional mov't
- Adiadochokinesia: unable to do rapid alternating mov'ts
- Rebound Phenomenon: loss of interaction between agonist & antagonist muscles
- Dysmetria: pass pointing phenomenon; extremity over shoots target
- Decomposition of movement: voluntary movement is jerky, discrete motions rather than smooth movement
- Visuospatial deficits: Flocculonodular lobe

Gait –Related Assessments

Emphasis on Balance & Gait Extremity Mov't

SARA: Scale for the Assessment & Rating of Ataxia

- Balance: 18 of 40 pts
- 3 items assess balance in sit, stand and during gait
- Originated for degenerative spinocerebellar atrophy, but valid across other cerebellar etiologies

ICARS: International Cooperative Ataxia Rating Scale

- Balance: 22 of 100 pts
- 19 items w/ 4 subscales:
  - Posture and Gait Disturbance – 7 items
  - Kinetic Function
  - Speech Disorder
  - Oculomotor Disorders
- Originated for hereditary ataxias

Rehabmeasures.org

Systematic Review of Literature[12]

- Posturography
- Berg Balance Scale: original for community dwelling older adults as risk for falls; regularly utilized for CVA population
- Posture Assessment Scale for Stroke: ability to change or maintain a lying down, sit, or stand position

Cerebellar Tests of Activity Limitation[11]	Gait Observations[11]
Gait: natural, narrow & tandem Spd: preferred vs fast Vision: with/without Perturbations: self vs external Surface Variation: typical of environment Hand(s): occupied Complex Gait: turns, backwards, sideways	1. Speed (10 ft; 10MWT) 2. Irregularity of step hgt & distance 3. Veering/walking path 4. LOB 5. Seeking UE support/guarding 6. Leg dyssynergia 7. Decomposition (stiff knees, reduced ankle motion) 8. Wide BOS 9. Truncal sway 10. Kinetic tremor 11. Need for Assistive Devices/orthotics 12. Distance 13. Need for human assistance

The client displays irregular hip and knee flexion and extension during swing phase. What may result when the foot touches the ground?

a. Equal stride compared to opposite LE
b. Varied foot placement
c. Consistent heel strike
d. Controlled knee extension with terminal swing

Poll Question 5

Treatment Interventions

To Improve Gait Impairments Related to Cerebellum Brain Lesions

[6,13-14]Tx depends on…..

1. Lesion location, size & severity: **Vermis; Paravermis; Lateral hemisphere & cortex versus subcortex – nuclei involvement (afferent vs efferent)**
2. Brainstem involvement: **bc arterial system crosses brainstem; lower on brainstem with swallowing/vertigo/N&V – not promising**
3. One time event with potential to improve **(recovery)** or degenerative in nature **(compensation)**
4. Social Determinants of Health

Rehab Tx Emphasis[15-22]

1. Static & dynamic balance activities
2. Coordination activities
3. Muscular endurance – aerobic activities or multiple reps with a timing component
4. Virtual reality
5. Biofeedback (visual & auditory)
6. BWSTT: Body Weight Support Treadmill Training
7. Torso Weighting
8. Sensory Techniques (Theraband)

Weight the Trunk, Not the Extremities

Gibson-Horn, 2008[19]

- Small amt of wgt placed asymmetrically via a vest based on directional LOB
- .5 lb vest w/ an extra 1.5 lbs placed at navel b/c of a tendency to lose balance backwards
- immediately on weighting, less sway in quiet standing, ↑d stability when perturbed, improved body alignment & < ataxia during gait."
- accomplished more challenging activities w/ better balance while weighted
- Fxnl improvement in walking & improved control during balance activities demonstrated in later tx sessions w/o wgts

Why Not Extremities?[7-10]

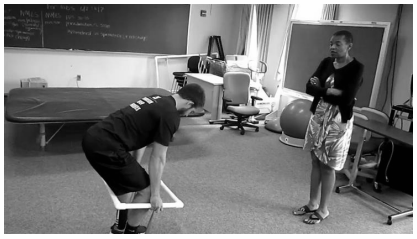
Lesion/impairment specific

To ↑ TRACTION thus facilitating movement by putting stretch on joint –resultant action mm contraction

eg not appropriate for cerebellar or sensory ataxia – applying wgt to ankles

Ataxia tends to increase after wgts removed

Theraband at Trunk or at Feet to Engage the Trunk



Use Theraband to Control the Extremities

Use Theraband to Control the Extremities

Timing for Emphasis

Use of Trunk Stabilization & Locomotor Training

Freund & Stetts, 2010[18]

- Trunk stabilization: abdominal drawing –in maneuver (contraction of transverse abdominus=TA) in supine, sidely, quadruped, standing & during functional activities 10 reps w/ 10 sec hold
- LT BWSTT requiring 3 people (pelvis & each LE); progressed from .6 mph holding onto treadmill 40% BWS to 2.0 mph w/o hand support & 20% BWS no assist from trainers
- Over ground walking

Kaufman & Schilling, 2007, p. 456 (Buzzard, 1998)[21]:

Proprioception

- "…as the sense of the position and movement of the limbs and body in space. Proprioceptive information is transmitted from receptors found in muscle, joints, ligaments, skin, and other soft tissues to the central nervous system."

Static	Dynamic
Use of weighted items such as vests, cuff weights	Engage in activities where force is exerted: push, pull, or carry using own body weight, such as climbing, facilitated weight shifts

Load the Extremities[21-22]

61

Load the Extremities[22]

Load the Extremities – Fixed Distal Point[22]



Load the Extremities during Fxnl Tasks[22]


Visual Input During Gait1[6,20]

Image A shows the patient mid-ambulation with no visual cues. She demonstrated an ataxic gait pattern, including scissoring of her lower extremities. Image B shows the patient ambulating with visual cues. Parallel lines of blue tape were applied to the floor and the patient was encouraged to place her feet on the lines during ambulation. This improved her foot placement and decreased the scissoring of her lower extremities.

Derks, 2015[20]

Proprioceptive Input

Pressotherapy[17]

Airsplint - PANat

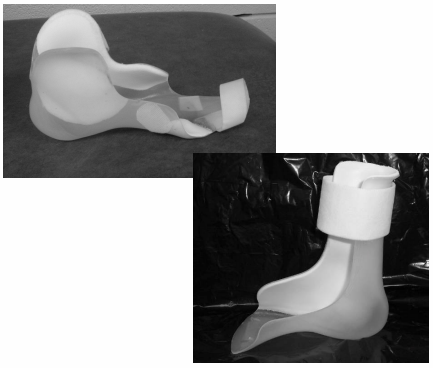
Virtual Reality Tools[23]

Requires:

- Balance
- Multi-segment coordination
- Cognitive component
- Gaming may increase adherence to therapy – motivation to compete against system

AFO & Theraband for Sensory Input for Accurate Foot Placement

- Least restrictive AFO



Theraband

Assistive devices: Do Not Weight RW (jvb)

Key is up right posture and trunk stabilization

Physical Therapy Management[14]

- Energy conservation techniques to help with fatigue
- Resistance may increase fatigue
- Try different exercises: Proprioception Neuromuscular Facilitation (PNF)
  1. Alternating isometrics
  2. Rhythmic stabilization
- Customize home ex program, based on
  1. pt level of fxn
  2. CG level of assistance/training/understanding
  3. home environment

The client displays irregular movement of the UE when placing the cane prior to taking a step. The PT opts to have the client _____.

a. practice arm swing
b. hold onto parallel bar while stepping forwards and backwards
c. jump up and down
d. do a prone push up

Poll Question 6

Patient & Family Education

Communicate clearly before & after tx to summarize interventions

Ask if there is understanding of intervention purpose and how to perform/modify

Promote and encourage safety

Case Study

A Home Balance Exercise Program Improves Walking in People with Cerebellar Ataxia

Amy Bastian & Jennifer L. Keller

Neurorehabil Neural Repair. 2014 October ; 28(8): 770–778. doi:10.1177/1545968314522350.

Background

- Characteristics of gait ataxia linked to balance deficits
- Restoring fxnl mobility to a safe level complicated by the fact that cerebellum contributes to motor learning
- Current research finds that these pts may benefit from long-term motor training w/ a supervised exercise program

Purpose

- Would a home based exercise program improve locomotor & balance abilities
- What influences walking speed? Age, ataxia severity, exercise duration, level of balance challenge

Methods

- Leg coordination plays less of a role than balance deficits on gait ataxia, therefore HEP consisted of static and dynamic balance activities than gait-directed activities
- Cerebellar damage due to degenerative dz confirmed by MRI or CT scan AND primary problem was ataxia at least mild as confirmed by ICARS for at least 3 mos
- 14 subjects completed study

Study Protocol

- Home-based balance exercise program for 6 wks & attended 5 training sessions (2 pre-training, 1 mid-training, 2 post-training)
- Assessments at baseline, 3wks, 6 wks & 4 wks after study ended

Assessment Tools

- ICARS
- Fine touch of great toe Semmes Weinstein Monofilaments
- Proprioception of great toe
- Spasticity
- Hyperreflexia

Gait & Balance

- DGI
- TUG
- Fxnl Reach
- Activities Specific Balance Confidence Scale (ABC)

Assessment Tools Continued

- Static Standing Balance measured by postural sway 2x 20 seconds; arms across chest & feet shoulder width apart EO & EC via a force plate and software
- Walking Speed 12-m walkway (main outcome)
  1. Stride length
  2. % Double limb support

Intervention

- HEP was tailored for each subject by PT based on baseline tests
- Surfaces: standard chair, 6 in dense foam, exercise ball (standard or peanut shape) or balance disc
- UE support varied in sit & stand to holding onto something stable with both hands, 1 hand or no hands
- Exercises start with stabilizing in a challenging static position & progress to dynamic UE/LE movement in same or modified position
- Warm-up session allowed if needed to get use to equipment
- Dosage: 3-5 min each ex for total minimum 20 min/day, 4-6/wk
- Rate exercise confidence 0-100 scale

Interventions Based on Info Learned

1. Tailored HEP
2. Surfaces
3. UE support
4. More stable to least stabile activity

1. Depends if lesion is primarily vermis, paravermis lateral hemisphere
2. More stable to least stabile surface or activity; more BOS to less BOS
3. Remove UE support to challenge balance

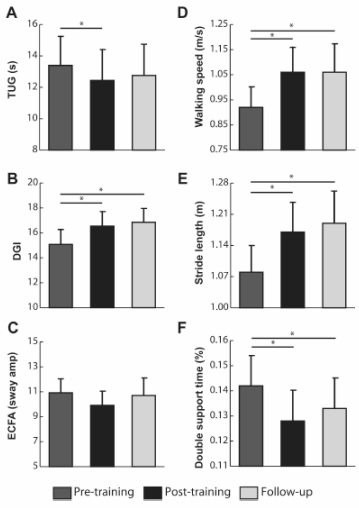
Outcomes

	PRETest
ICARS	39± 15
Gait/Posture	15± 7
DGI (median) 14	6-22
TUG	15.2± 9.5
Fxnl Reach	12.25± 3.25
ABC (median) 61%	36-85%
Walking spd fast pace	0.9± 0.3 m/s
Stride length	1.08± 0.22m
% stance time	64± 4 sec

Overall, subjects compliant with HEP

11/14 subjects: >3 or more days/wk

10/14 subjects: 60% confidence w/ ex

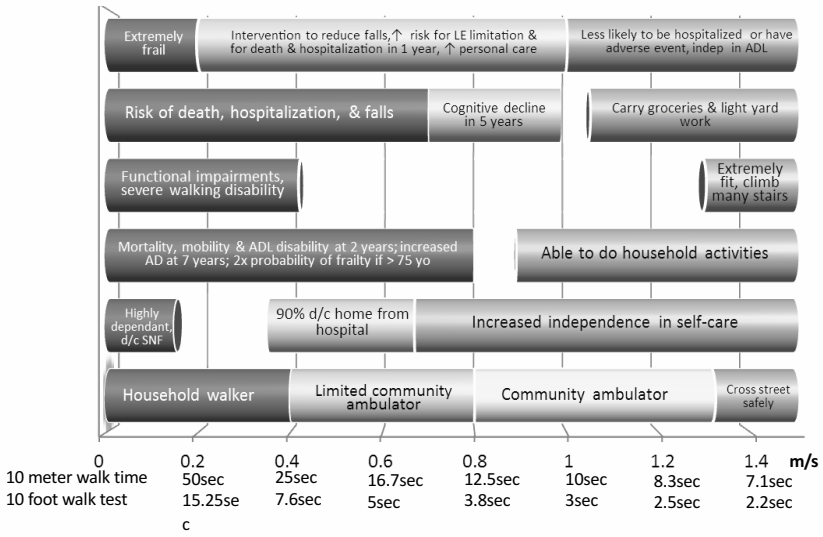


Outcomes

Significant change across all phases

1. **DGI (p <0.001)**
2. **Walking Speed (p <0.001) 15% increase**
3. **Stride length (less variability) (p <0.001)**
4. **Double limb support time (less time both feet on ground, therefore taking more steps) (p <0.01)**

Walking Speed Evidence Across Studies Middleton, Fritz, Lusardi JAPA, 2015



8/16/2017

Discussion & Take Home Message

- Subjects could benefit from home base program & is effective; therefore 1:1 PT visits not needed – cost saving
- Level of challenge to balance most important than duration of exercise in producing positive effects – change in walking speed
- Walking speed is 6th vital sign associated with QOL (Fritz & Lusardi, 2009) & (Middleton, Fritz & Lusardi, 2015)
- Standing ex limited to dynamic UE and trunk mov't from a stable starting point; dynamic activity during walking too challenging to be done safely

Discussion & Take Home Message

- ICARS & ABC scores did not change over 13 weeks –perhaps due to fact that the measures did not reflect changes relevant in the study;
  - perhaps ICARS not sensitive to subtle changes that occurs in a short period of time
  - Subjects may not remember last time they did the activity being asked on ABC scale
- Compliance in terms of frequency & quality limited by self-report of subject and demonstration at 3 & 6 wks & f/u; therefore, for subjects who did not feel confident to challenge themselves, could have benefit from supervised sessions

Based on this study, cerebellar ataxia was verified by _____?

a. CT
b. MRI
c. ICARS score
d. All of the above

Poll Question 7

Knowledge Summary

Key Points

- In terms of treating cerebellar patients: recovery is dependent on whether insult is a one time event (location, size, severity) or degenerative in nature
- Ataxia is a "catch all term," but assess pt according to where damage is: vermis, paravermis or lateral hemisphere with gait-related cerebellar tests
- Use standardized measures in addition to traditional tests that measure gait speed & use Tests of Activity Limitation - specific for cerebellar gait deficits and denote observations

Key Points

- Gait ataxia is a problem of balance and not leg discoordination – therefore include static & dynamic balance activities
- Weight the trunk appropriately according to sway pattern and load the extremities in a variety of positions; close kinetic chain activities prior to open kinetic chain – sensory input into the system important
- Theraband can limit excessive movement and provide a stabilizing force to the trunk and extremities
- Incorporate cognitive component to treatment

Question and Answer Period

Test Time

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